

FACILITIES FOR METEOROLOGICAL RESEARCH
AT THE NASA GODDARD/WALLOPS FLIGHT FACILITY

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1. INTRODUCTION

The Wallops Flight Facility of the NASA Goddard Space Flight Center has established the Atmospheric Sciences Research Facility (ASRF) to support the development of a vigorous atmospheric research program. This Facility is built around two ultra-sensitive, high-resolution, coherent radar systems, and includes a Lightning Research Facility, consisting of several different lightning measurement instrumentation systems; an Applied Physics Measurements Laboratory, equipped with several different ozone spectrophotometers, and related instrumentation; and, an Environmental Data Acquisition and Recording System.

Wallops has other instrumentation systems which are not part of ASRF, but are frequently used to support investigations conducted at ASRF. These include other coherent radars, a radio-sonde launch facility, meteorology rocket facilities, a meteorological forecast unit, a real-time display of the National Weather Service WSR-57 radar located at NAS, Patuxent River, and several aircraft on which instruments can be mounted. A real-time video display of satellite images should be available by summer 1983.

This report describes the technical characteristics of the Atmospheric Sciences Research Facility, discusses improvements being made to the instrumentation which will enhance its usefulness in atmospheric research, and describes several of the on-going research programs. It also serves as an introduction to the facility to potential users and invites them to use it for their own research.

2. ATMOSPHERIC SCIENCES RESEARCH FACILITY

The ASRF consists of the Radar Atmospheric Research Facility (RARF), the Lightning Research Facility (LRF), the Applied Physics Measurement Laboratory (APML), and the Environmental Data Acquisition and Recording System (EDARS). The Facility is fully supported by data displays, data handling equipment, data processing computers, and operating personnel.

2.1 Radar Atmospheric Research Facility (RARF)

The RARF consists of two separate research and development radar systems. One operating in the UHF-band (70 cm) and the other in the S-band (10 cm). The Facility was constructed in the late 1950's for a program involving atmospheric re-entry of missile payloads. Since 1965, the Facility has been used almost exclusively for atmospheric research projects. Simultaneous measurements in the UHF- and S-bands can be made of clouds and precipitation to deduce particle size and characteristics including quantitative cross sections of individual hailstones and raindrops. Relative attenuation at these wavelengths can be used to calculate path-integrated rainfall and water content. (Cox & Masterson, 1969)

The S-band radar, called the Space Range Radar (SPANDAR), has two transmitters: A high-power transmitter with a peak power output of 5.0 megawatts and a low-power transmitter with a peak power of 1.3 megawatts. Both have a 10 MHz bandwidth over a frequency band of 2700 to 2900 MHz. For meteorological measurements both transmitters are controlled by a frequency diversifier. The diversifier shifts the transmit frequency of each radar pulse by the reciprocal of the pulse width, thus making each pulse independent in frequency from every other pulse.

Frequency diversity allows for the accumulation of a large number of independent meteorological echoes at a much faster rate than normal; it rejects second-time-around targets, and it inserts a calibration signal for receiver drift compensation.

The return signal is stored on tape and is displayed in real-time on color video monitors. The display can be either a Plan Position Indicator (PPI) or a Range Height Indicator (RHI). The range normalized reflectivity is contoured into six separate color levels. An Aircraft Position Indicator (API) places the position of an aircraft, being tracked by another radar, on the PPI as a flashing dot. The displays can be remoted to any site which can receive standard WSR weather radar data.

A color graphics computer is being integrated into the system for use in 1983. This will provide for multiple displays, such as PPI scans and RHI scans, as well as doppler mean velocities and spectral variance whenever doppler processors are attached to the system.

At the moment, RARF does not have a doppler processor. In the past, any group who used the radar supplied their own real-time doppler data processor. Wallops is planning to add a permanent doppler capability to the radar by CY 1984.

In addition to the incorporation of the color graphics system and the upgrading of the radar for doppler processing, the radar computer system is being replaced with a Data General Eclipse S-130 microcomputer. This will greatly increase the data collection and analysis capabilities of the radar.

The UHF radar is a coherent, wide bandwidth, high-power, 70 cm wavelength radar with peak transmitter powers of over 6 MW and a bandwidth adjustable up to 50 MHz. The broad bandwidth allows the radar to take pulse-to-pulse and pulse-shape data. The coherent output allows for doppler velocity measurements to be made. The long wavelength makes the radar ideally suited to detect lightning channels without serious attenuation from rain along the beam path.

The received signal from the UHF radar can be displayed and recorded only by using the SPANDAR data processing electronics. Therefore, simultaneous display or recording from both radars is not possible. As the SPANDAR data recording system is upgraded, the existing system will be dedicated to the UHF.

This past summer, the UHF radar was used to locate regions of lightning in real-time. The radar energy reflected from the ionized channel was recorded on video and analog tape for study and analysis.

The technical characteristics of the RARF radars are given in Table 1.

2.2 Lightning Research Facility

The Lightning Research Facility (LRF) consists of four lightning detection and measurement systems. Three of these systems detect and measure the RF radiation emitted from an electrical discharge and the fourth senses the change in the magnetic field due to the electrical discharge. These systems are the Lightning Detection and Ranging (LDAR) System (Poehler & Lennon, 1979);

TABLE 1
Relevant Parameters of
the RARF Radars

	SPANDAR	UHF
Frequency (MHz)	2700 to 2900	420 to 450
Peak Power Output (MW)	1.0 or 5.0	1.0 to 6.0
Minimum Detectable Reflectivity or Cross Section Per Unit Volume at 10 km (cm ⁻¹)	10 ⁻¹⁷	10 ⁻¹⁹
Pulse Length (Microseconds)	1, 2, or 5	0.1 to 6.0
Beam Width (Degrees)	0.39	2.9
Sensitivity (db)	-119	-112

the Goddard/Georgia Tech Sferics Data System (LeVine & Krider, 1977); the Lightning Location and Protection (LLP) System (Krider, et al, 1980); and the Ryan Stormscope.

The LDAR was originally developed at NASA Kennedy Space Center to detect potential hazardous electrical activity that might impair space launch operation. Wallops acquired it in 1979 and put it into operation in 1981.

LDAR measures the times of arrival of the pulsed RF radiation emitted by an electrical discharge. This RF radiation is detected by VHF antennas at outlying sites and relayed to a central station where the spatial location of the discharge is determined. This signal is recorded on digital tape and the raw data on analog tape. The location of source of RF signals is plotted on both a PPI display and an RHI display. The position accuracy within 15 km of ASRF is better than 1% (Poehler, 1978) and decreases with increasing distance. Quite usable data can be obtained for distances as far as 110 nautical miles.

The Goddard/Georgia Tech Sferics Data System measures the RF radiation characteristics of lightning at selectable wavelengths from 3 MHz to 300 MHz. Normally, wavelengths of 3 MHz, 30 MHz, 70 MHz, 139 MHz, and 295 MHz are used. The system is capable of measuring slow and fast electric field changes generated by the lightning.

Vertically polarized radiation is detected by vertical quarter-wave

monopole antennas for each frequency except 3 MHz where a base-loaded monopole antenna is used. Horizontally polarized radiation is detected by resonant (half-wave) dipoles at 139 MHz and 295 MHz. Electric field changes are detected by a flat plate antenna. The RF and electric field measurements are recorded on magnetic tape for later reduction. A chart paper recording provides a real-time output.

For a more complete description of the system, see LeVine & Krider (1977); LeVine (1978); and LeVine (1980).

The LLP is a commercial direction finding (DF) system designed to plot locations of cloud-to-ground lightning flashes within nominal ranges of 100, 200, or 400 kilometers. It requires two or more antenna sites for triangulation. The antennas are orthogonal loop antennas which sense the magnetic field of the lightning flash. The DF system processes the data for each stroke and transmits them to a position analyzer (PA) which computes and maps the ground stroke locations. The DF also displays lightning times, angles, signal strengths, and other characteristics of the strokes. (Krider, et al, 1980)

Antenna sites are located at NASA Wallops; NASA Langley Research Center, about 80 nm southwest of Wallops; and, the Naval Research Facility, Dahlgren, Virginia, about 90 nm northwest of Wallops. These three sites form a point-to-point system which is embedded within a larger multidrop system of the State University of New York (SUNY) at Albany. The multidrop system includes sites in New Jersey, Pennsylvania, and New York. Table 2 gives technical specifications for the system.

The Ryan Stormscope is primarily designed for use in an aircraft to provide bearing and range information of electrical discharges relative to the aircraft. Radio frequency signals, generated by electrical discharges, are picked up by a single flat-pack antenna which provides both the V and H direction loop antennas and an electrical sense antenna. The system records and displays up to 128 individual electrical discharges as small green dots on the CRT and automatically updates the "oldest" discharge information with the "newest."

For an evaluation of the Stormscope, see Baum & Seymour (1979).

2.3 Atmospheric Physics Measurements Laboratory

The Atmospheric Physics Measurements Laboratory (APML) was

TABLE 2
LLP System

Range	100, 200, or 400 km.
Detector Efficiency	90% of all flashes within range.
Angular Accuracy	1 degree or better.
Unwanted Signal Rejection	Filters for 50 or 60 Hz. Shape rejection of noise and out of range signals.
Multiple Strokes	Up to 14 return strokes per flash.
Communications	Point-to-point, multidrop, or dial-up. (Selectable baud rate up to 4800 baud.)
Outputs	Analog X- and Y-axis voltages: Time of discharge (to 0.1 sec.). Azimuth angle (to 0.1 Degree): Signal Strength - Number of return strokes.

established in 1979 to support an inter-comparison among several different spectrophotometers used to measure the total ozone content in a column of the atmosphere. (Parsons, et al, 1982A) As now configured, the APML has a Dobson spectrometer, a Canterbury filter spectrophotometer, a Sentran filter photometer, and a NO_x sensor. Also under development is a Michelson interference spectrometer which will allow the measurement of atmospheric constituents from the ultra-violet through the near infra-red regions. (Parsons, et al, 1982B)

2.4 Environmental Data Acquisition and Recording System

EDARS is a general purpose data acquisition and recording system designed to record data from environmental sensors. EDARS presently collects data from two types of sensors; ozone sensors and a wind data system. The ozone sensors are located at AMPL and the wind data sensors are on the 300-foot meteorological tower on Wallops Island. The system is designed to record data from up to 50 different sensors with input rates up to 1,000 parameters per second.

Available data that can be interfaced into the system include:

1. Ozone data from dasibi sensors.
2. Radiosonde data.

3. Wind data from remoted sites.
4. Daily weather summaries.
5. NO_x chemical sensor data.
6. Hydrocarbons chemical sensor data.
7. Hourly weather observations.
8. ASRF support summaries.

3.0 ACTIVE PROGRAMS

Atmospheric research using these facilities has been conducted at Wallops since long before the establishment of ASRF. From the early 1960's through 1977, the Air Force Cambridge Research Laboratory and the Applied Physics Laboratory of Johns Hopkins University used the radars for investigations of clear air turbulence, insect and bird detection, rain-rate determinations, rain attenuations studies, and similar studies. Results of these studies have been reported in numerous publications and at the Meteorology Radar Conferences. More recently, the major emphasis has been on providing support for the NASA Storm Hazards Program conducted by NASA Langley Research Center and the COMSTAR Communications Experiment run by the Applied Physics Laboratory of the Johns Hopkins University.

The Storm Hazards Program is a major facility user during the thunder-storm season. This program contains a number of different, but interdependent, experiments. The overall goal of the program is to improve the knowledge of severe convective storms and how they affect aircraft design and operation.

An F106B aircraft storm penetration experiment is the keystone of the entire program. It involves flying the highly instrumented jet aircraft into thunderstorm cells to measure the effects of turbulence, direct lightning strikes, and heavy rain on the aircraft structure and the avionics. On-board instruments measure current, current change, the time rate-of-change in electric and magnetic fields, and total charge, as well as 3-axis accelerations. Other experiments measure the X-ray and optical signature of the lightning, the chemistry of convective thunderstorm cells, and the water thickness on the airplane skin during encounters with heavy rain.

An AFGL turbulence experiment uses the F106B aircraft accelerometer data to

correlate with the turbulence measured in the radar volume by the SPANDAR radar.

A Langley airborne doppler radar experiment uses the F106B data as an in situ measure of turbulence. This data is correlated with measurements made with a K-band doppler radar in the Wallops Skyvan (NASA 430) airplane.

A Wallops/University of Oklahoma experiment uses the UHF radar to actively detect lightning channels in order to provide high-range resolution of lightning activity in a small region of space.

An AFGL passive lightning detection study uses a large (60-foot) microwave dish to detect the natural radiation created by lightning activity. Closely related is a cooperative experiment conducted by Rome Air Force Base to detect any radiation at 430 MHz generated by the airplane itself.

The Severe Storm Dynamics Investigation is a Wallops program that seeks to understand the nature of severe storms and the correlations among the parameters characterizing such storms. The experiment utilizes the vast amount of data that can be collected at ASRF to study storm properties.

In studies not connected with storm hazards, a COMSTAR communications experiment uses the SPANDAR radar to measure the amount of precipitation along an earth-to-satellite communications path. This data is used to develop rain fade statistics for high-frequency communications satellites.

The National Severe Storms Laboratory (NSSL) is conducting a wind profiling experiment which uses both radars in their most powerful and most sensitive configuration. They are attempting to measure the profile of the horizontal component of the wind from the ground up to the height of the tropopause.

4.0 PROCEDURES FOR USE

Since it was established in 1945, Wallops has maintained an open door policy to both government and independent investigators from the United States and abroad. The wide array of instrumentation facilities used on the rocket range has been made available to the scientific community to support many types of scientific studies. This policy applies to the ASRF as well. Currently, there is no user's fee attached to the use of the facility. Only those costs above and beyond normal operating costs are charged to the user.

More information about use of the facility can be obtained from either of the authors or by writing to the Director of Suborbital Projects and Operations, NASA Goddard Space Flight Center/Wallops Flight Facility, Wallops Island, VA 23337.

REFERENCES

- Baum, R. K., and T. J. Seymour, 1979: In-Flight Evaluation of a Severe Weather Avoidance System for Aircraft. AFFOL-TM-79-45-EES, GPO.
- Cox, Ronald, and Robert Masterson, 1969: Facilities for Atmospheric Research, Report No. 11, NCAR Facilities Laboratory.
- Krider, E. Philip, A. E. Pifer, and M. A. Uman, 1980: An Automatic Locating System for Cloud-to-Ground Lightning. Lightning Technology, Ed. Pitts, 205-214, NASA CP-2128.
- LeVine, D. M., and E. P. Krider, 1977: The Temporal Structure of HF and VHF Radiation during Florida Lightning Return Strokes, Geophys. Res. Lett., 4, 13-16.
- _____, 1978: RF Radiation from Lightning. NASA TM 78095.
- _____, 1980: Sources of the Strongest RF Radiation from Lightning, 1980. J. Geophys. Res. 85, 4091-4095.
- Parsons, C. L., J. C. Gerlach, and M. E. Williams, 1982A: An Inter-comparison of Ground-Based Total Ozone Instruments. J. Appl. Meteor., 21, 88-104.
- _____, _____, and M. Whitehurst, 1982B: A Fourier Transform Spectrometer for Visible and Near-Ultraviolet Measurements of Atmospheric Absorption. NASA TM 73297.
- Poehler, H. A., 1978: A Preliminary Test of the Application of the Lightning Detection and Ranging System (LDAR) as a Thunderstorm Warning and Location Device for the FAA. NASA CR-154629.
- _____, and C. L. Lennon, 1979: Lightning Detection and Ranging System (LDAR) Description and Performance Objectives. NASA TM 74105.